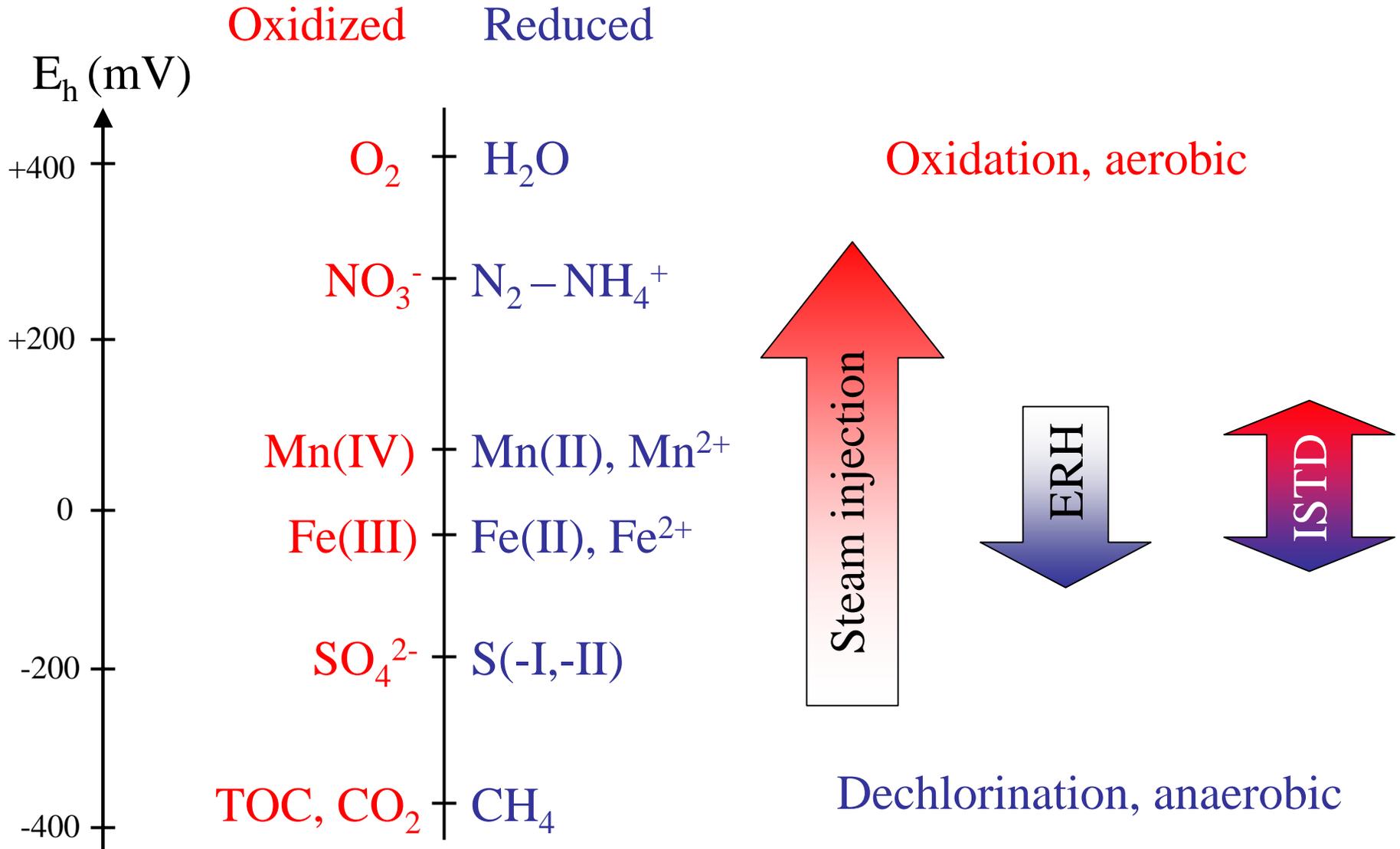


Redox ladder – electron donors and acceptors



Impact of thermal on redox

Steam injection:

Air: Reduce risk of NAPL condensation

Air: Enhance removal in vapor phase

Air/O₂: Stimulate degradation reactions

ERH:

Boiling under vacuum – removes dissolved gases such as O₂

Hydrogen formation around electrodes possible

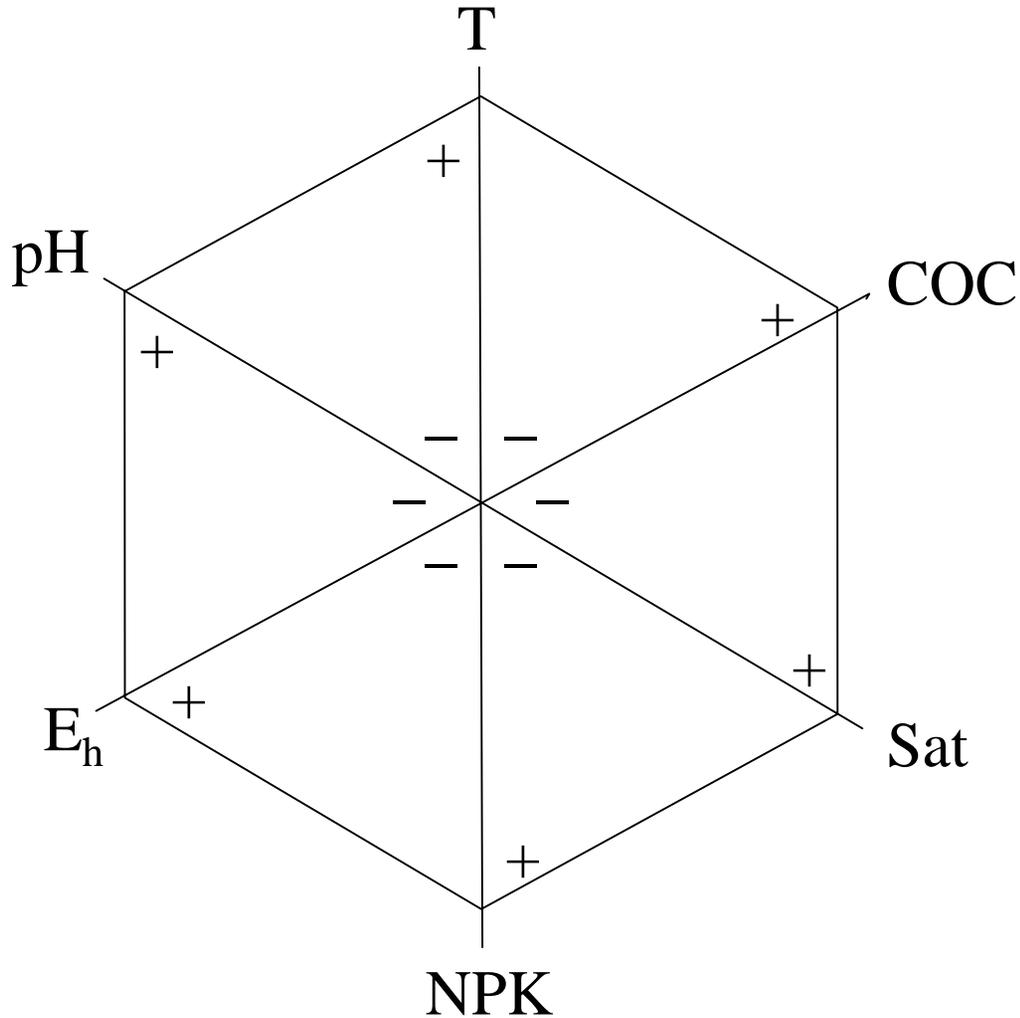
Reactions around Fe(0) used for electrodes

ISTD-TCH:

Boiling under vacuum – removes dissolved gases such as O₂

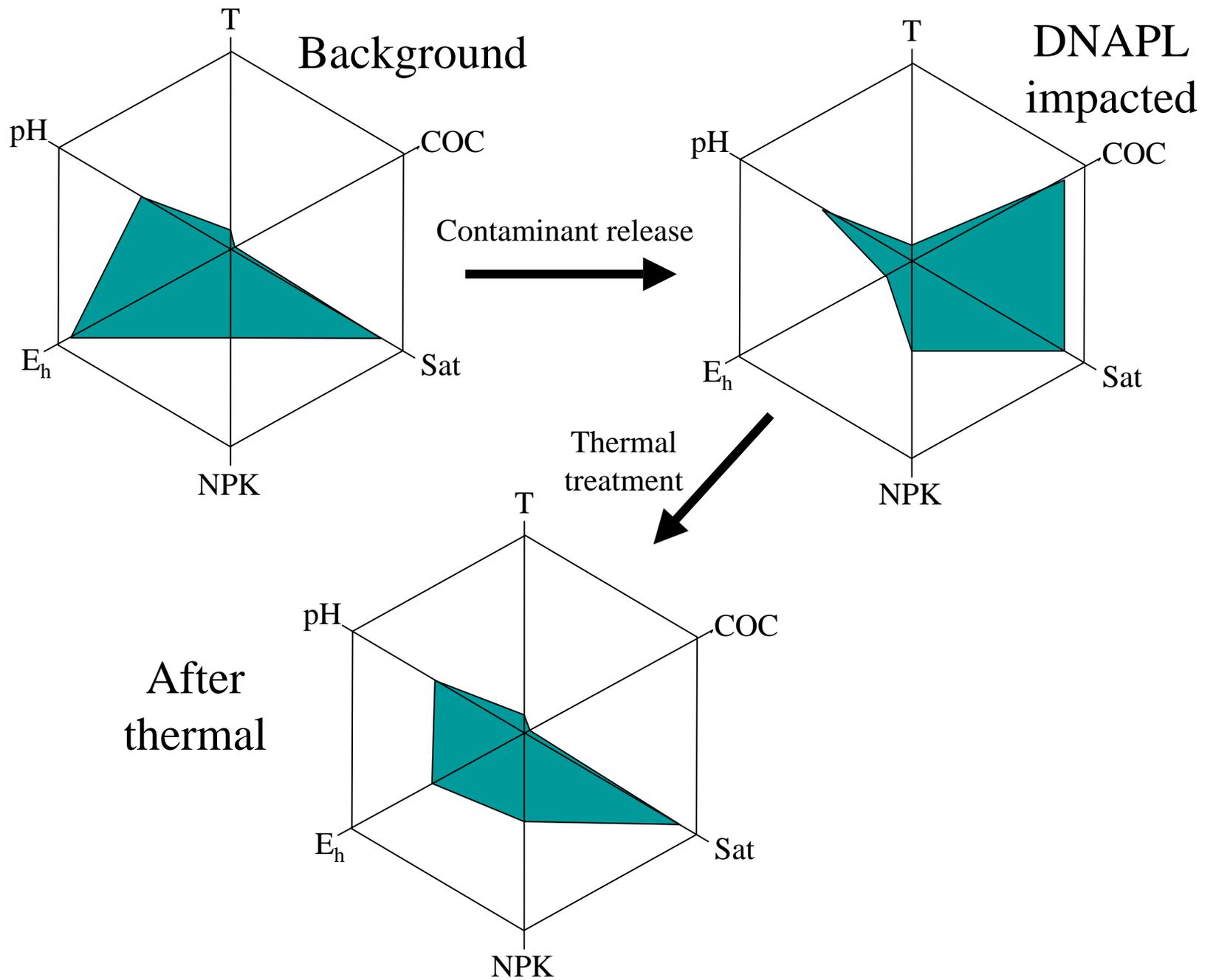
Air can be added for in-situ destruction

Environment diagram



Abbreviations

T	Temperature
COC	Contaminant concentration
Sat	Water saturation
NPK	Nutrient availability
Eh	Oxidation-reduction potential



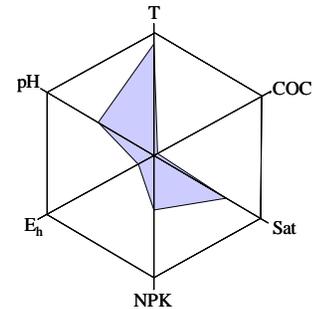
Conclusions

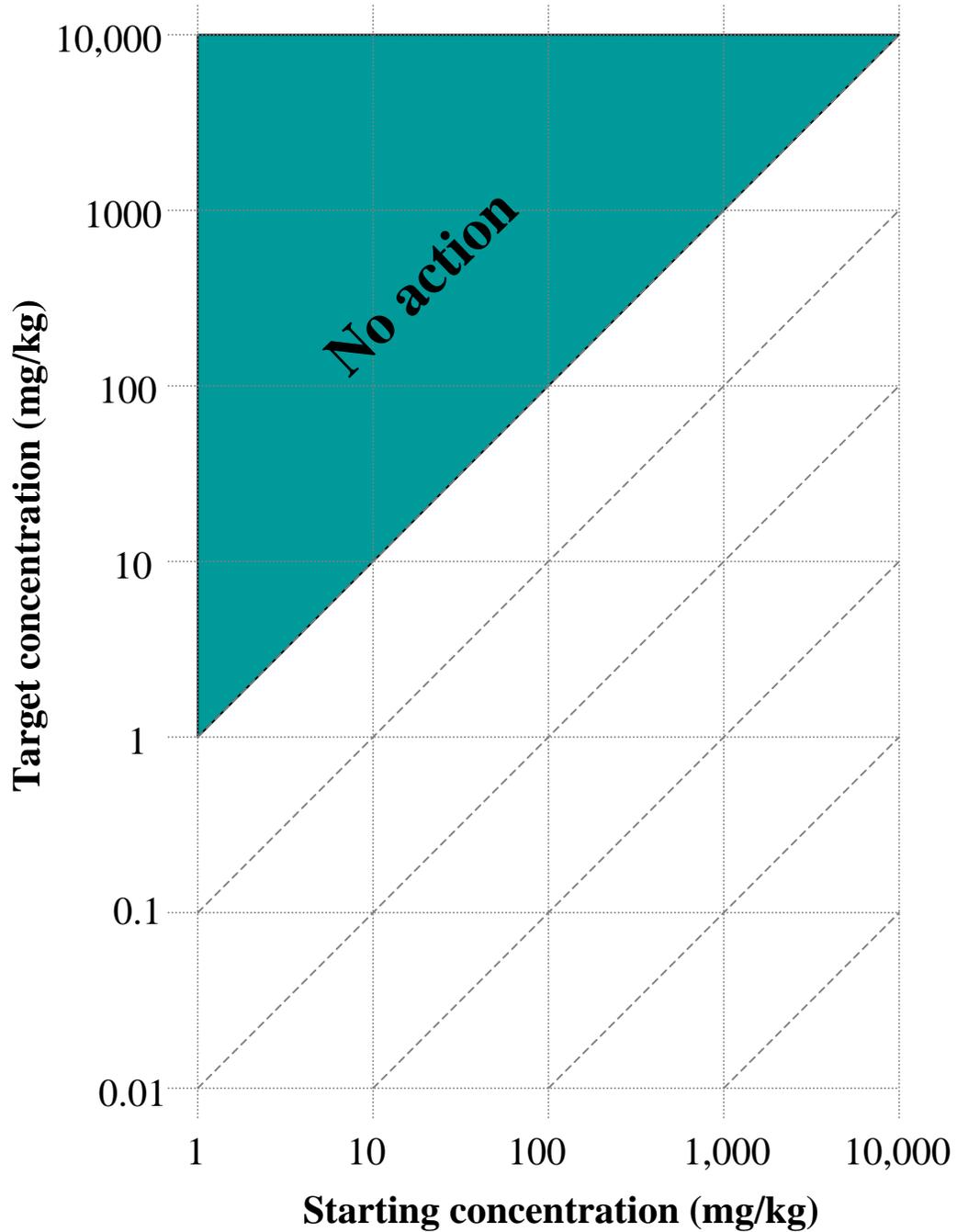
Redox chemistry is key for reactions

Geochemical changes can be significant during thermal

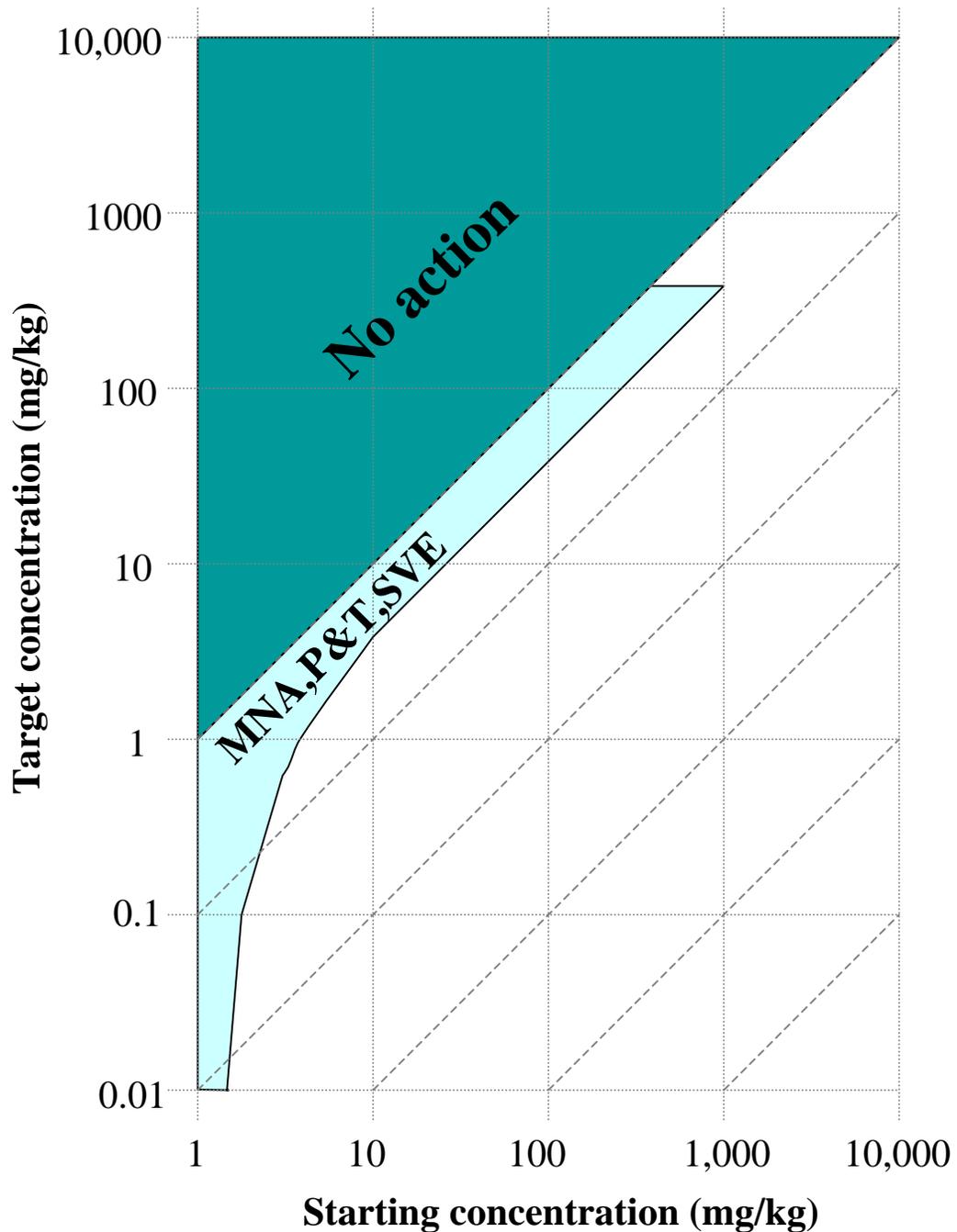
Bioremediation may

- be discouraged due to quick changes in environmental conditions (T, E_h)
- be encouraged by stimulation and augmentation with little competition

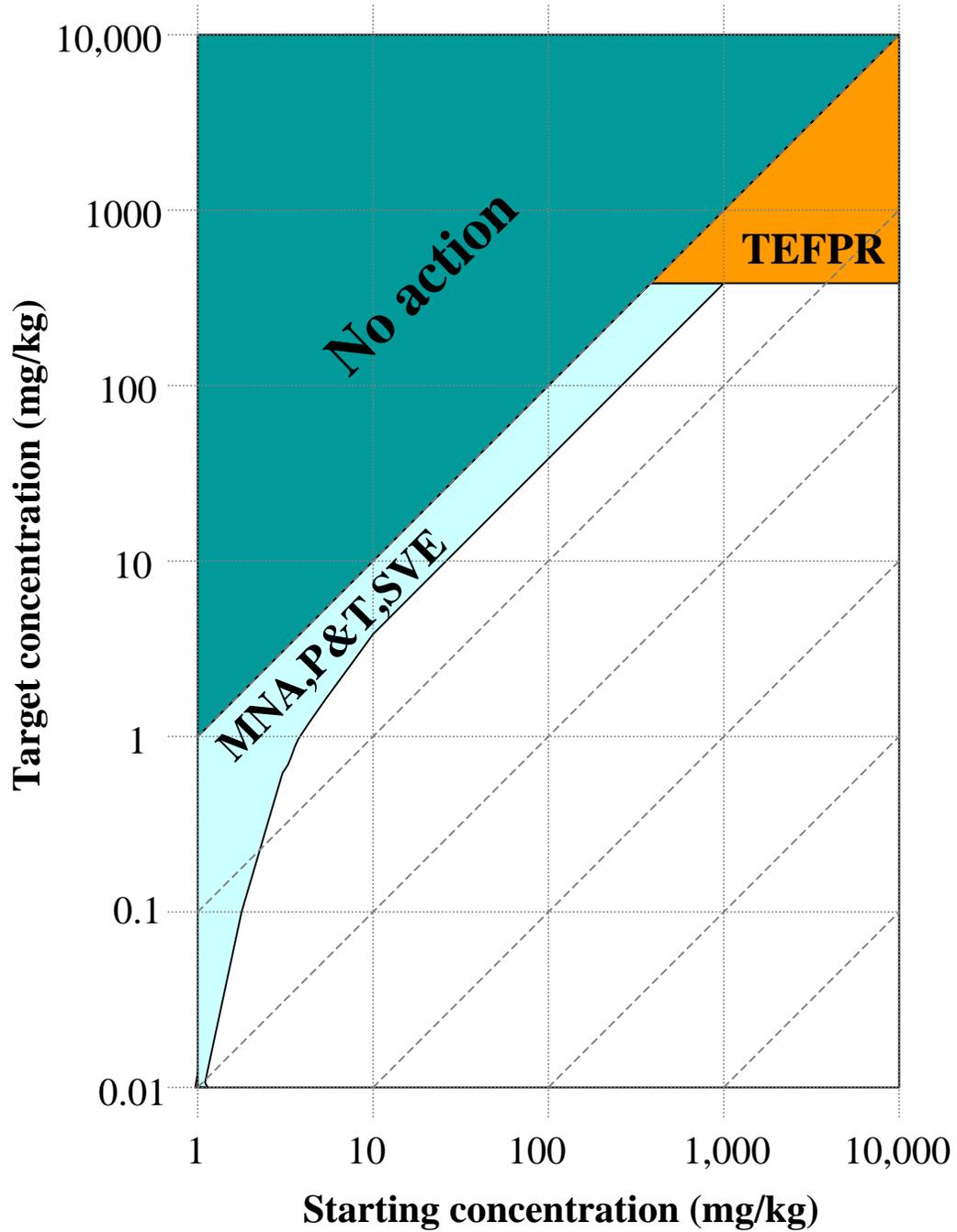




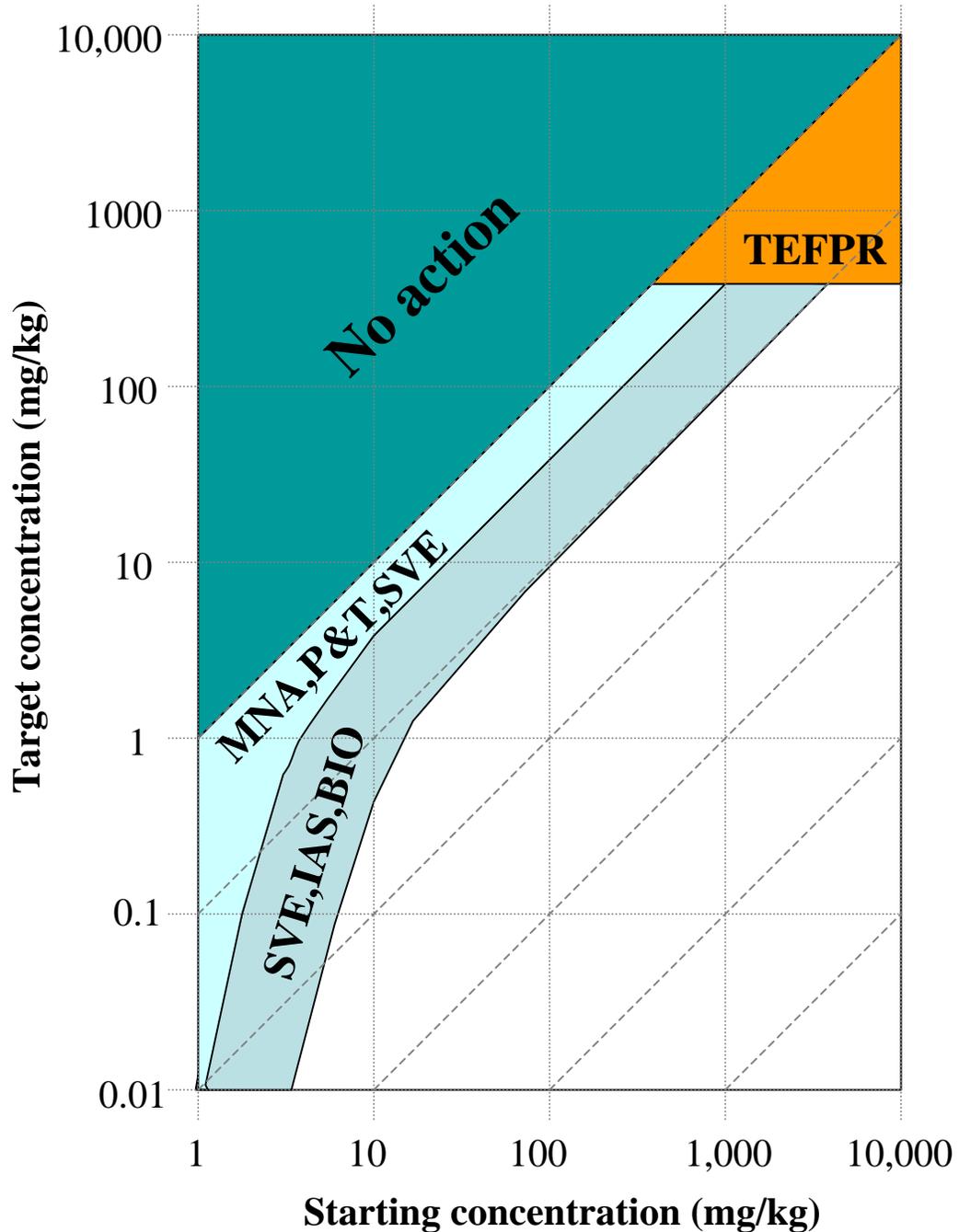
Domains for
treatment
options



Domains for
treatment
options



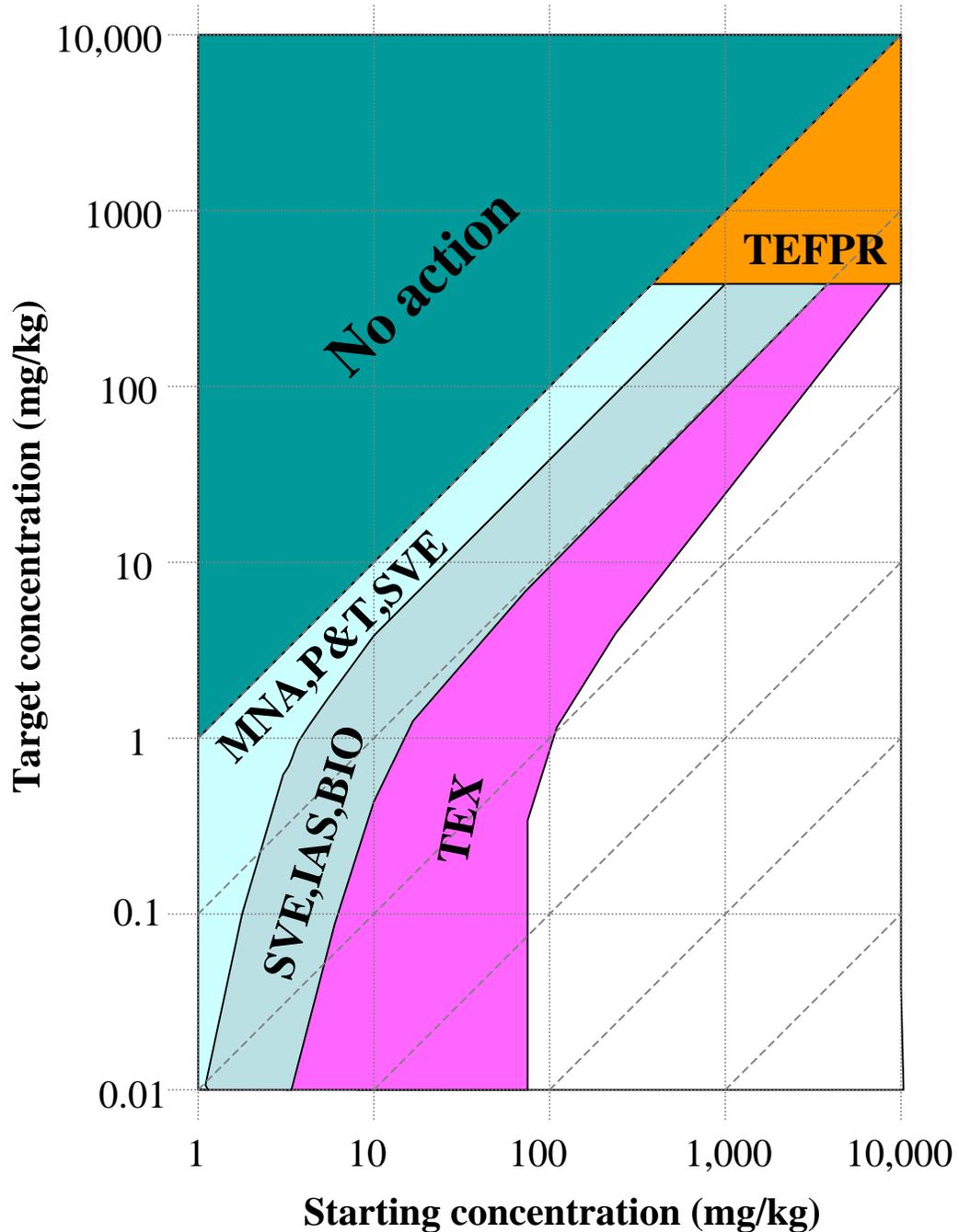
Domains for
treatment
options



Domains for treatment options

Abbreviations

TEFPR – thermally enhanced free product recovery

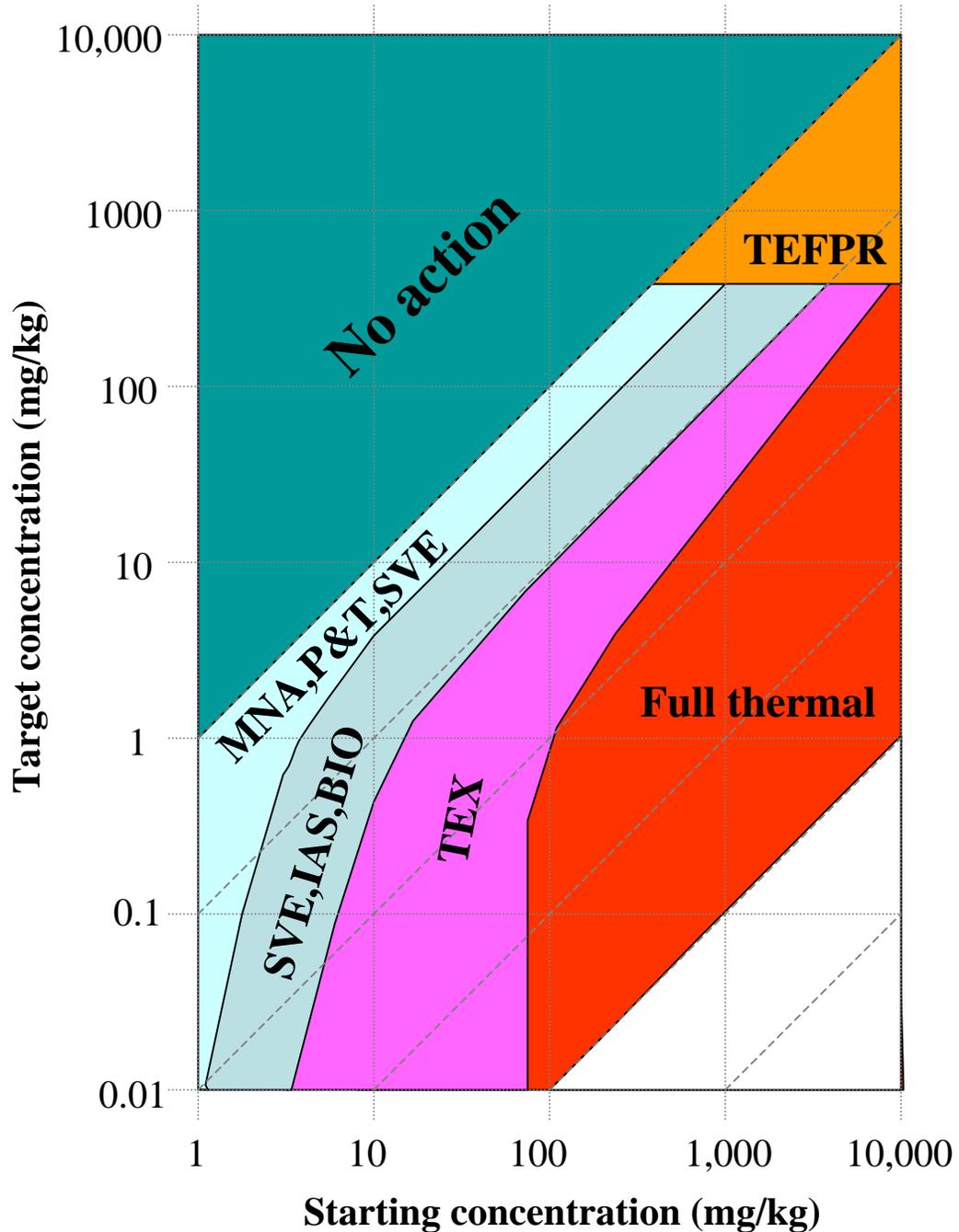


Domains for treatment options

Abbreviations

TEFPR – thermally enhanced free product recovery

TEX – thermally enhanced X

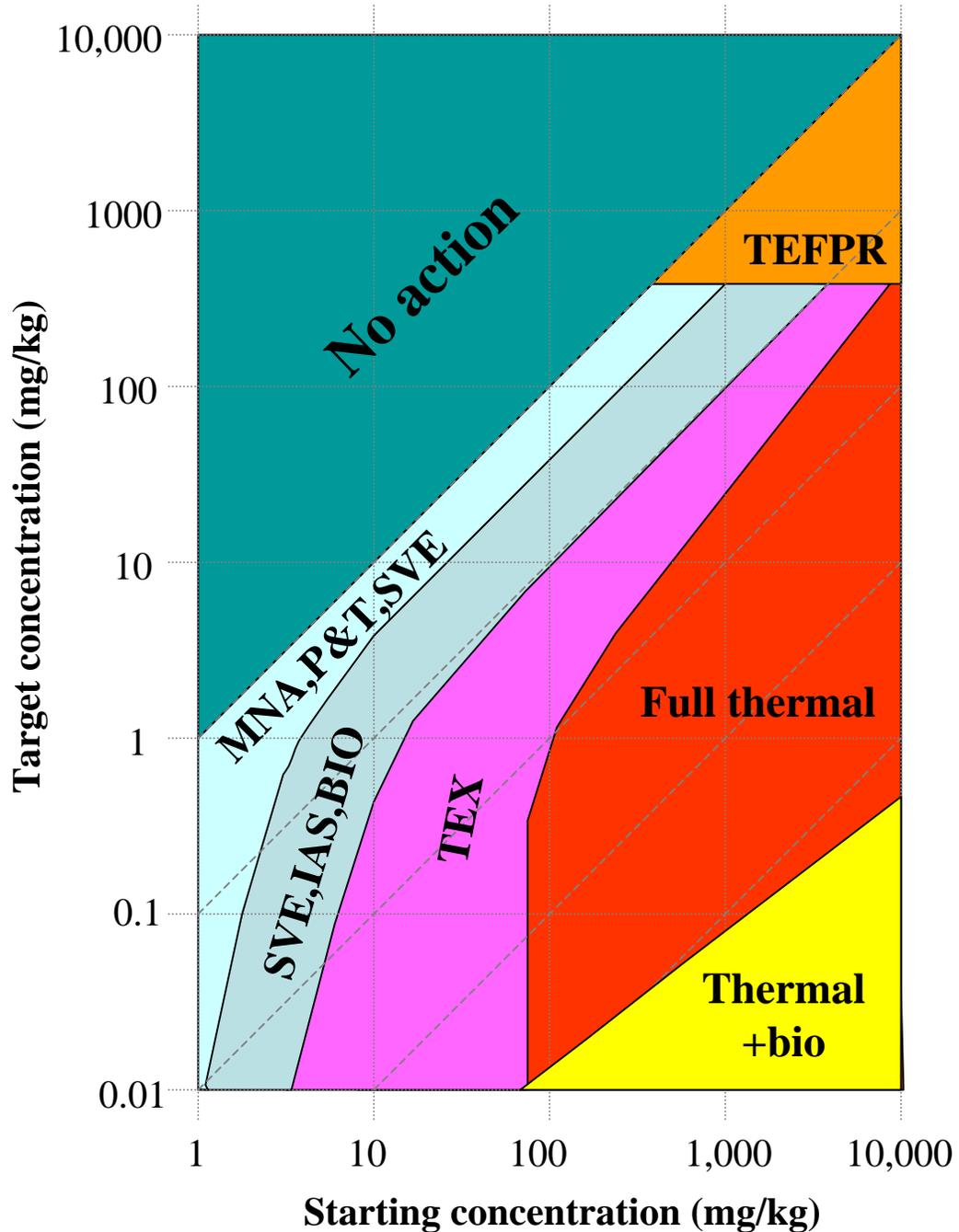


Domains for treatment options

Abbreviations

TEFPR – thermally enhanced free product recovery

TEX – thermally enhanced X

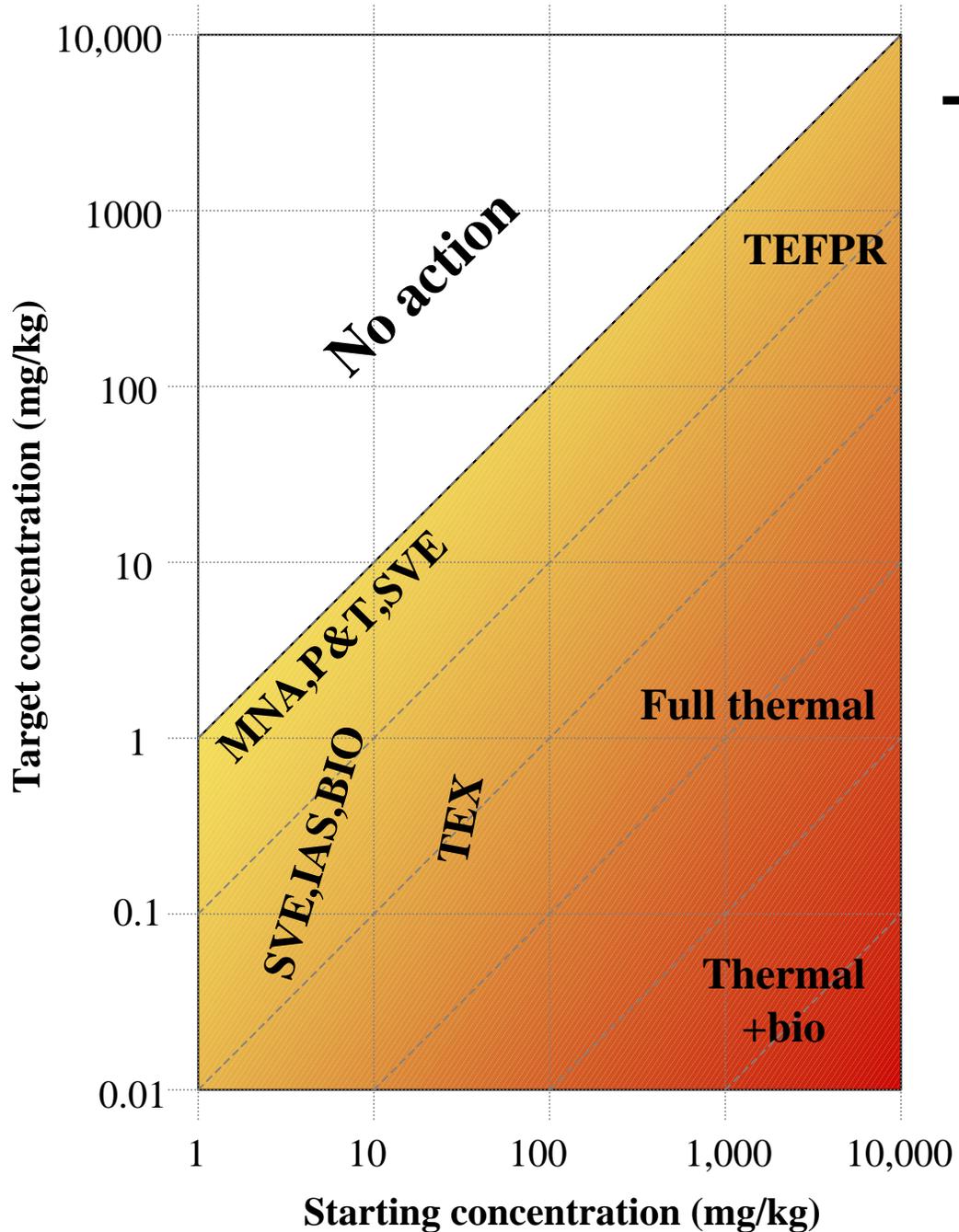


Domains for treatment options

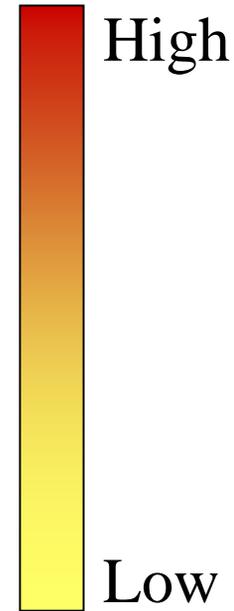
Abbreviations

TEFPR – thermally enhanced free product recovery

TEX – thermally enhanced X



Treatment cost



Combo not universally applicable
 Relatively high unit treatment cost
 Most relevant when remedial goals are very stringent and concentrations high

Conclusions

- It is not simple
- Heating above 40°C favors new microorganisms
- May be beneficial to augment after cool-down
- Geochemistry rules what happens
- Starting and target concentrations are essential
- Case by case evaluation – simple answers are dangerous
- Cost varies dramatically from site to site (so does the most economic technology)